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An overview of

ZigBee
and
IEEE 802.15.4

ZigBee® Alliance
Wireless Control That Simply Works

Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)

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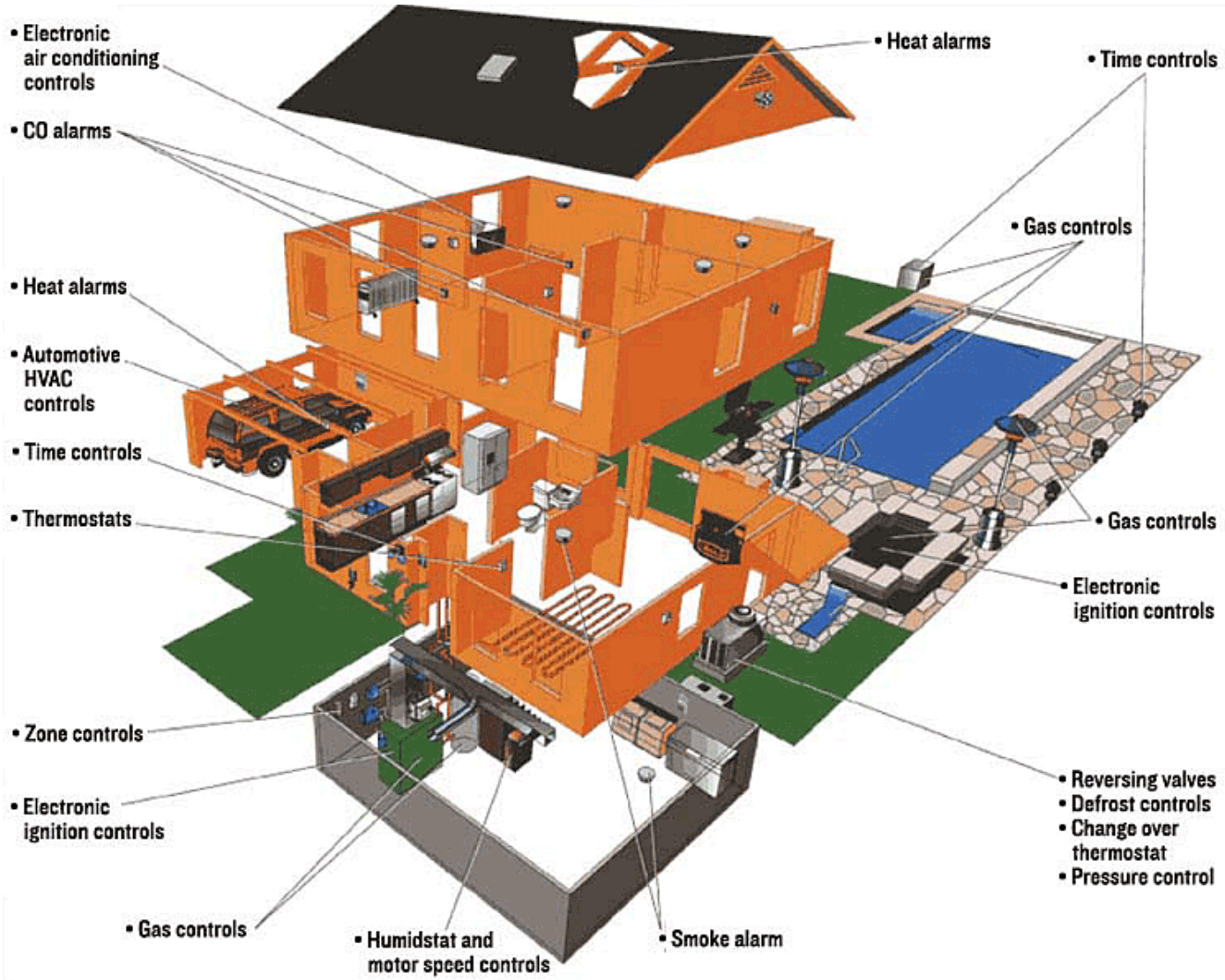
ZigBee is:

- Spans entire protocol stack (PHY to Appl.Layer)
- Complexity, cost and energy consumption < BT
- Low data rate
- Long battery life (duty cycle)
- Secure, robust networking
- Self organising / self healing network

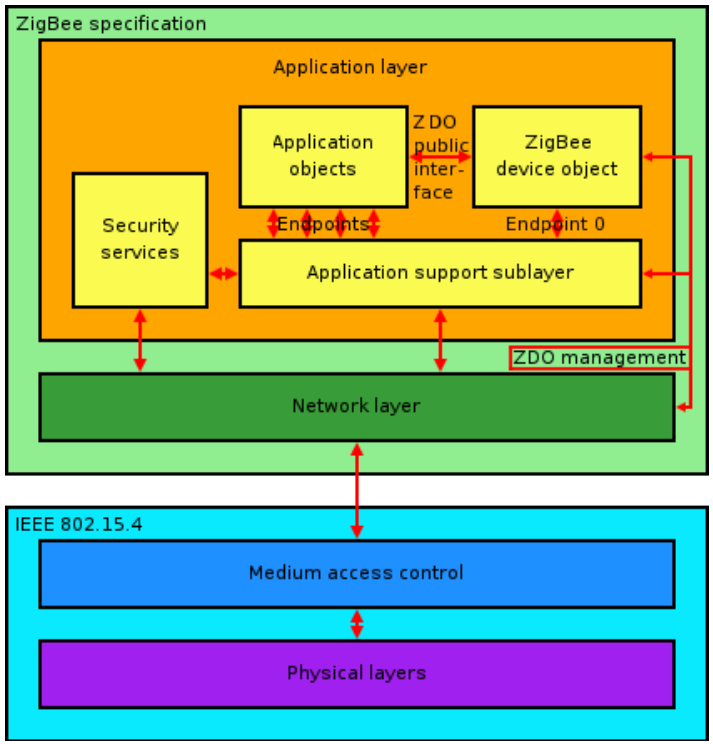
Applications:

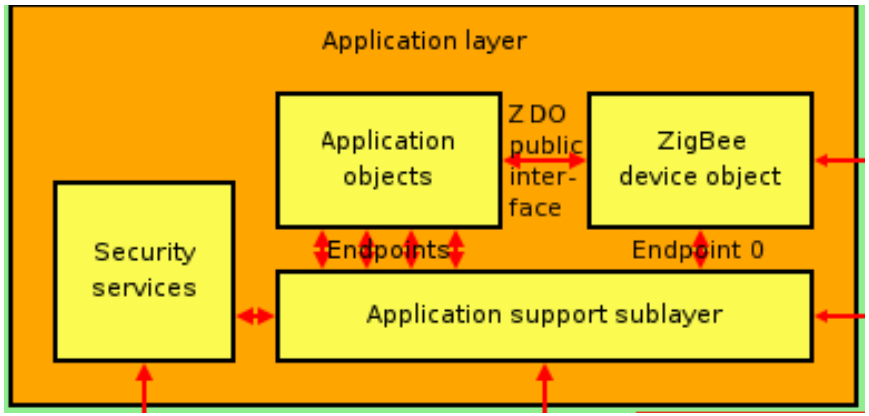
- Wireless Control (home, office, industry)
- Wireless Monitoring
- Home Automation
- $\longrightarrow$ Wireless Personal Area Networks (WPAN)
- $\longrightarrow$ Wireless Sensor Networks (WSN)


• Electronic air conditioning controls
• CO alarms
• Heat alarms
• Automotive HVAC controls
• Time controls
• Thermostats
• Zone controls
• Electronic ignition controls
• Gas controls
• Humidstat and motor speed controls
• Smoke alarm
• Heat alarms
• Time controls
• Gas controls
• Gas controls
• Electronic ignition controls
• Reversing valves
• Defrost controls
• Change over thermostat
• Pressure control

ZigBee protocol stack

- Layered like OSI model
- Application Layer
- Network Layer (routing)
- Medium Access Control
- Physical layer, Radio
- Profiles defined by ZigBee Alliance [1]
- MAC and PHY defined in IEEE 802.15.4 [2]





- Defines several profiles (similar to BT)
- Profiles enable interoperability
- With vendor-specific implementations
- Provides security (128 bit AES symmetric key encryption)
- All very nice ... but out of the scope of this talk

ZigBee knows three types of nodes:

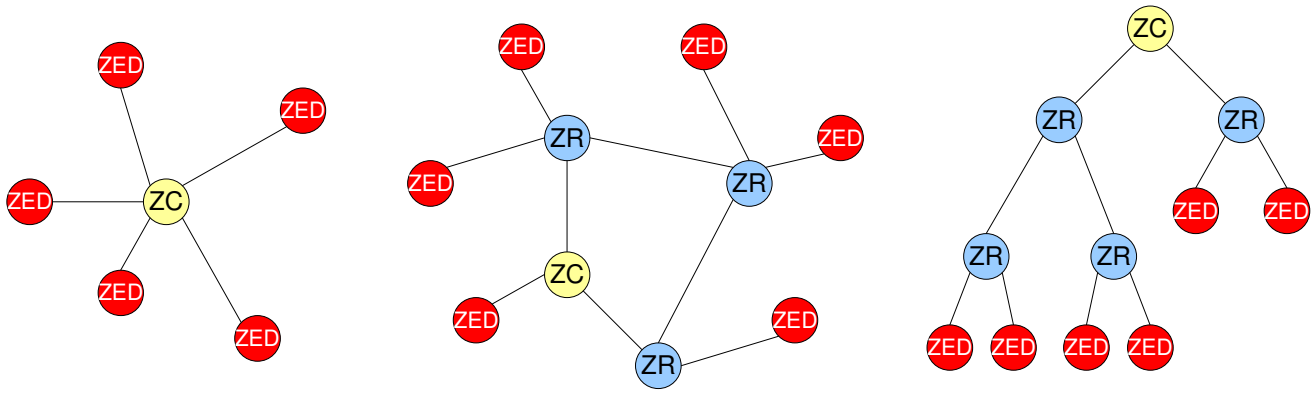
- ZigBee Coordinator (ZC) - 1 per network
- ZigBee Router (ZR) - *
- ZigBee End Device (ZED) - *

IEEE 802.14.5 knows two:

- Full Function Device (FFD)
- Reduced Function Device (RFD)
- but... defines a PAN-coordinator (which is a FFD)

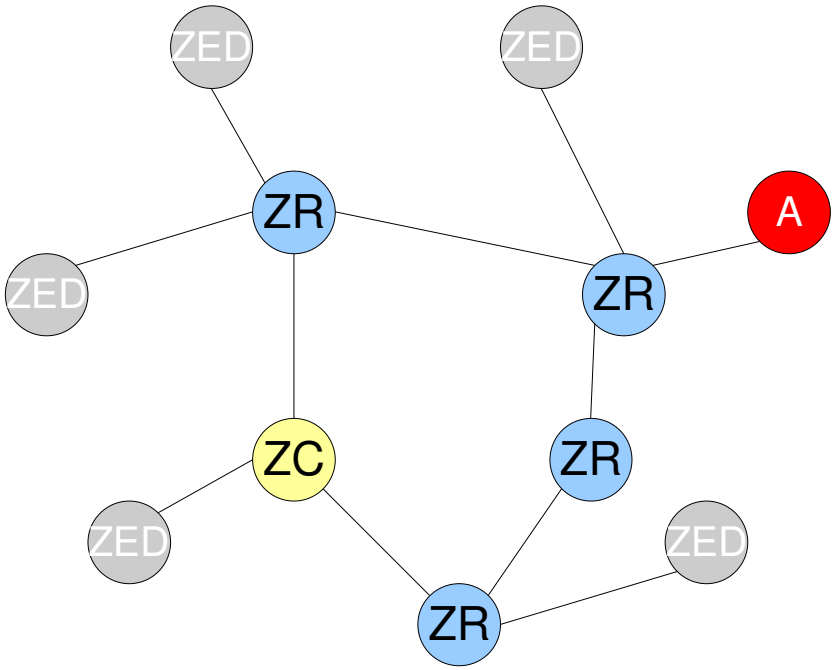
Network Topologies

- Routing with Ad hoc On-demand Distance Vector (AODV): build routes only when needed
- Allows multiple network toplogies, depending on application



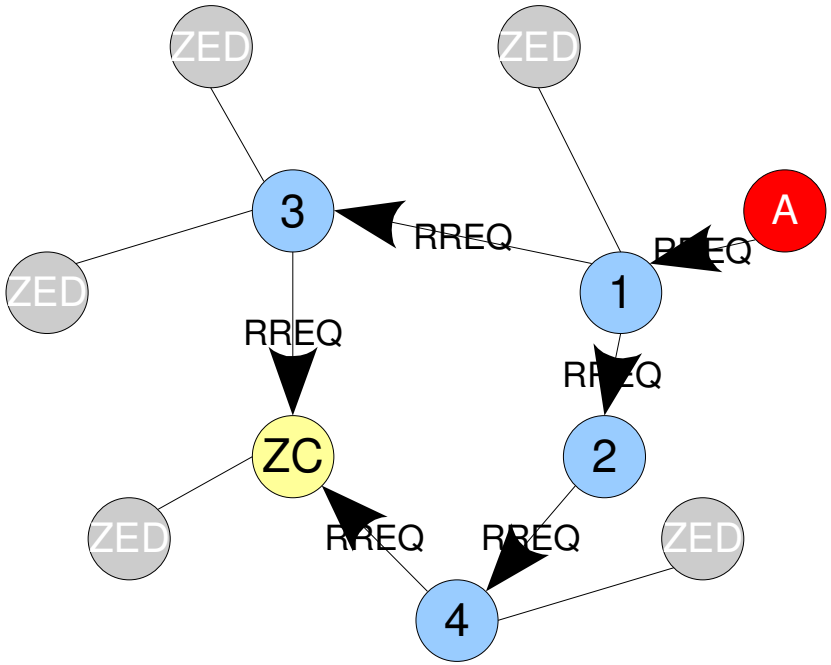
AODV Routing (RFC 3561 [4])

1. Node A wants to send data to Node ZC



AODV Routing (RFC 3561 [4])

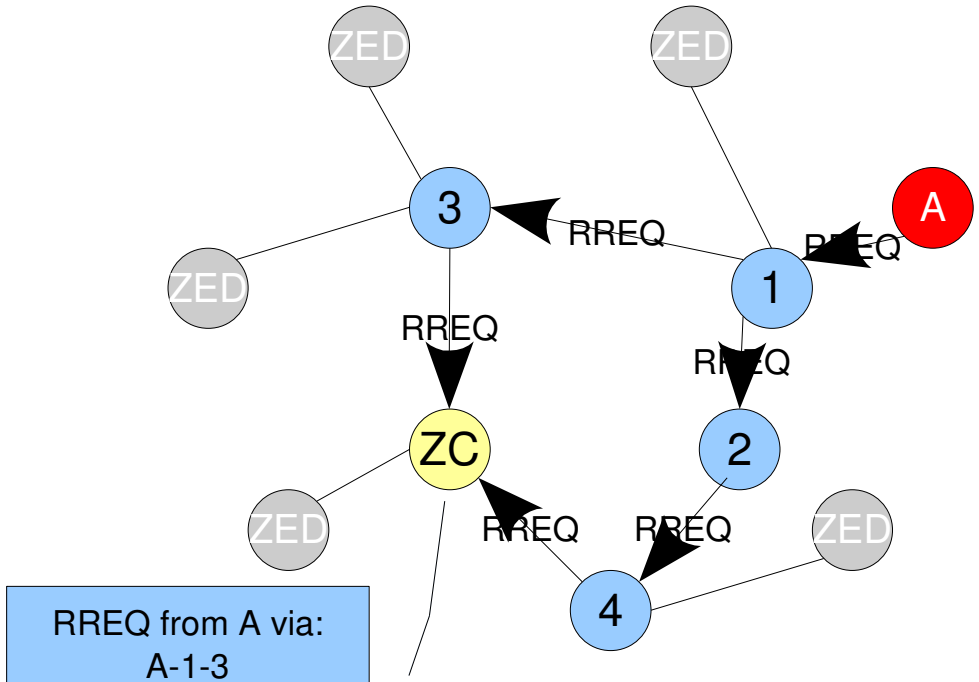
2. Node A floods RREQ for ZC



Flood RREQ

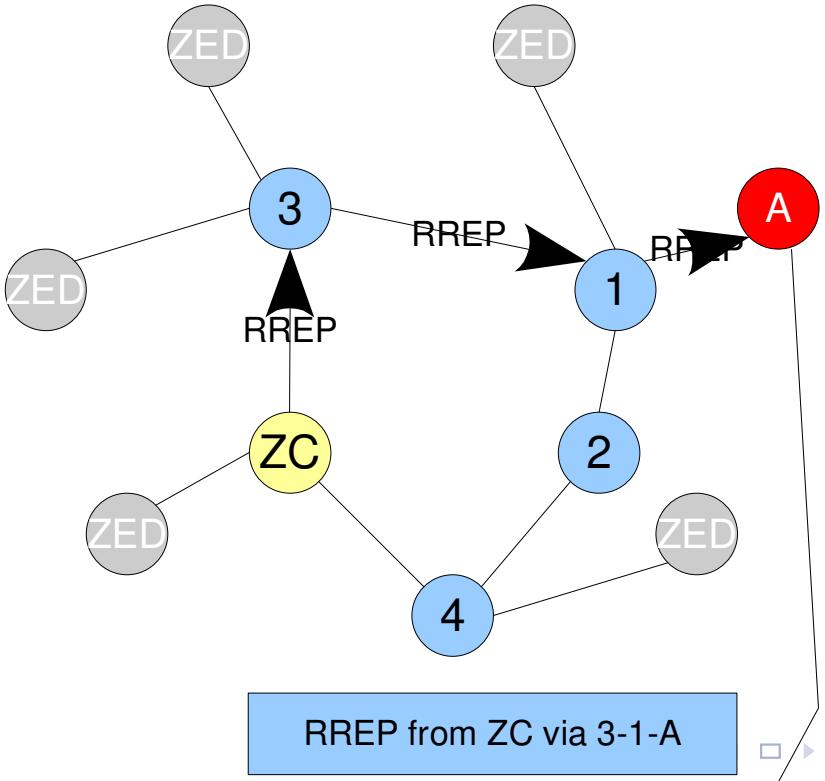
AODV Routing (RFC 3561 [4])

3. ZC receives RREQ



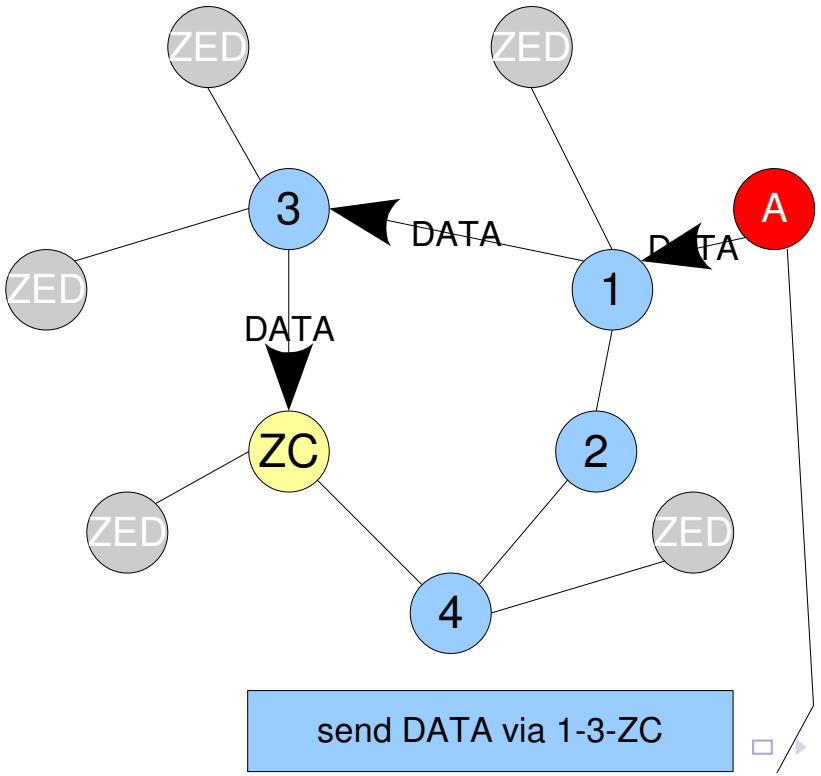
AODV Routing (RFC 3561 [4])

4. ZC unicasts RREP to A over shortest route

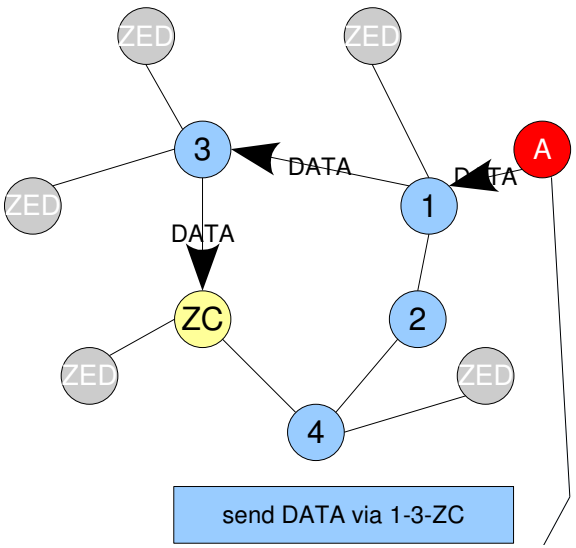


AODV Routing (RFC 3561 [4])

5. A sends DATA over shortest part



AODV Routing (RFC 3561 [4])



Benefits:

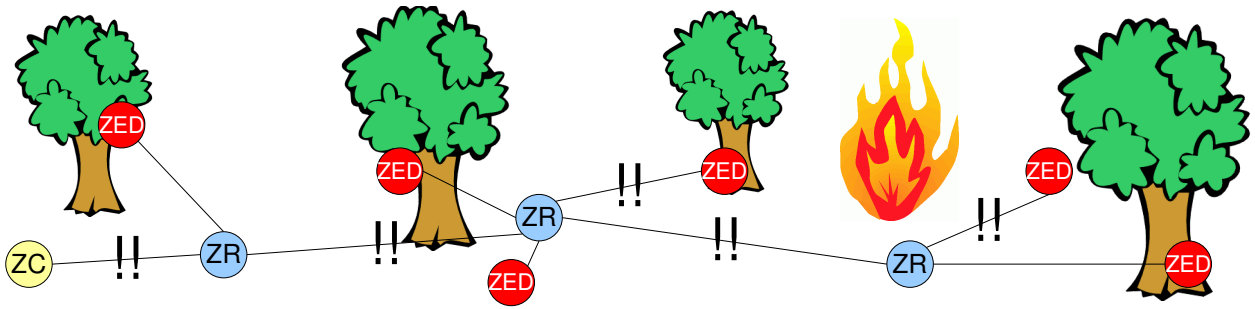
- Routes built when needed (no comm. otherwise)
- Route in RREP is accurate
- Low setup delay

Drawbacks:

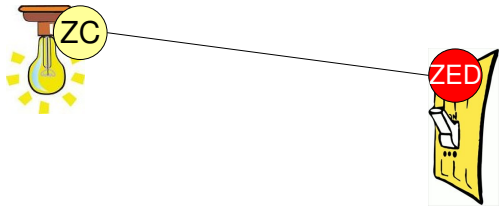
- Can have stale routes
- Flooding can be burden on network

- Ensures every node gets an opportunity to use the medium
- Two modes: Coordinated (“beacon-enabled“) and uncoordinated (”beaconless“)

beacon-enabled - (Slotted TDMA) ZR sends beacons, ZEDs sync. to beacons, wake up during beacon time. Sleeping enables long duty cycles.



beaconless - (CSMA/CA) Communication can occur at any time.



Only four frametypes are specified:

- **Beacon** - sent by coordinator's MAC, function is to coordinate
- **Data** - encapsulates upper-layer data
- **Acknowledgement** - used to signal correct reception at MAC
- **MAC Command** - MAC management info

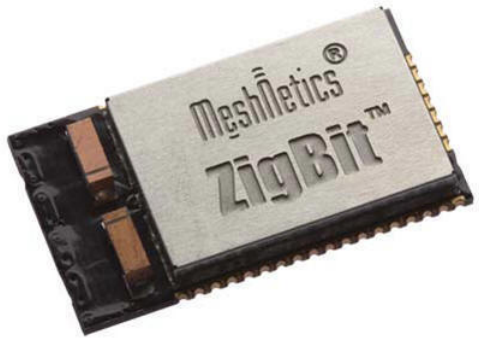
- Manages the radio (off to safe power)
- Selects channel
- Performs energy detection (CCA, Carrier Sense)
- Most important: transmits and receives information

Spectrum

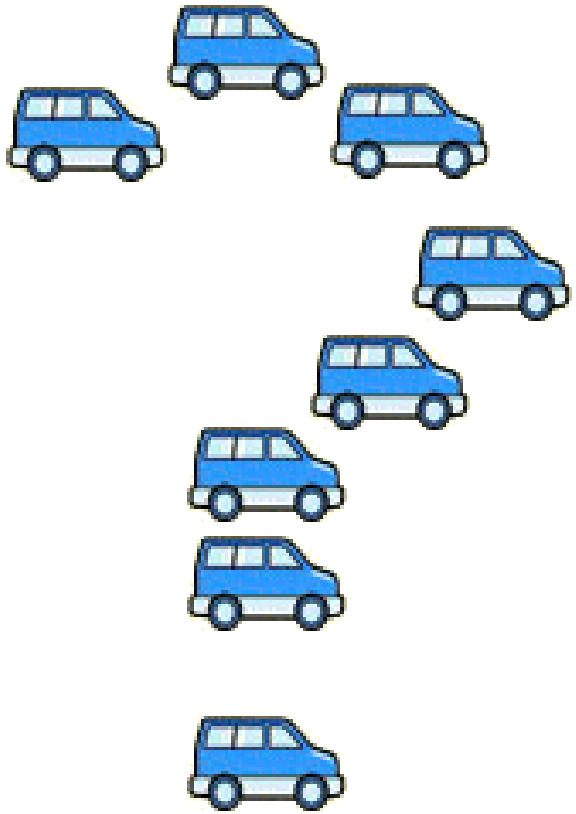
PHY (MHz)	Frequency band (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation	Bit rate (kb/s)	Symbol rate (ksymbol/s)	Symbols
868/915	868–868.6	300	BPSK	20	20	Binary
	902–928	600	BPSK	40	40	Binary
868/915 (optional)	868–868.6	400	ASK	250	12.5	20-bit PSSS
	902–928	1600	ASK	250	50	5-bit PSSS
868/915 (optional)	868–868.6	400	O-QPSK	100	25	16-ary Orthogonal
	902–928	1000	O-QPSK	250	62.5	16-ary Orthogonal
2450	2400–2483.5	2000	O-QPSK	250	62.5	16-ary Orthogonal

Modulated using DSSS, 868/915 can also use Parallel Sequence Spread Spectrum [3] $\Longrightarrow$ tradeoff between data rate, energy efficiency and multipath fading resistance at a low electronic complexity.

- Transmit power $\leq$ 1 mW
- Communication range 10-75m depending on environment and modulation
- Few analog stages, digital circuits whenever possible
- Radio and microcontroller (and sometimes antenna) often integrated in single chip



Questions?



Backup Slides

Frame structures [2]

Beacon frame

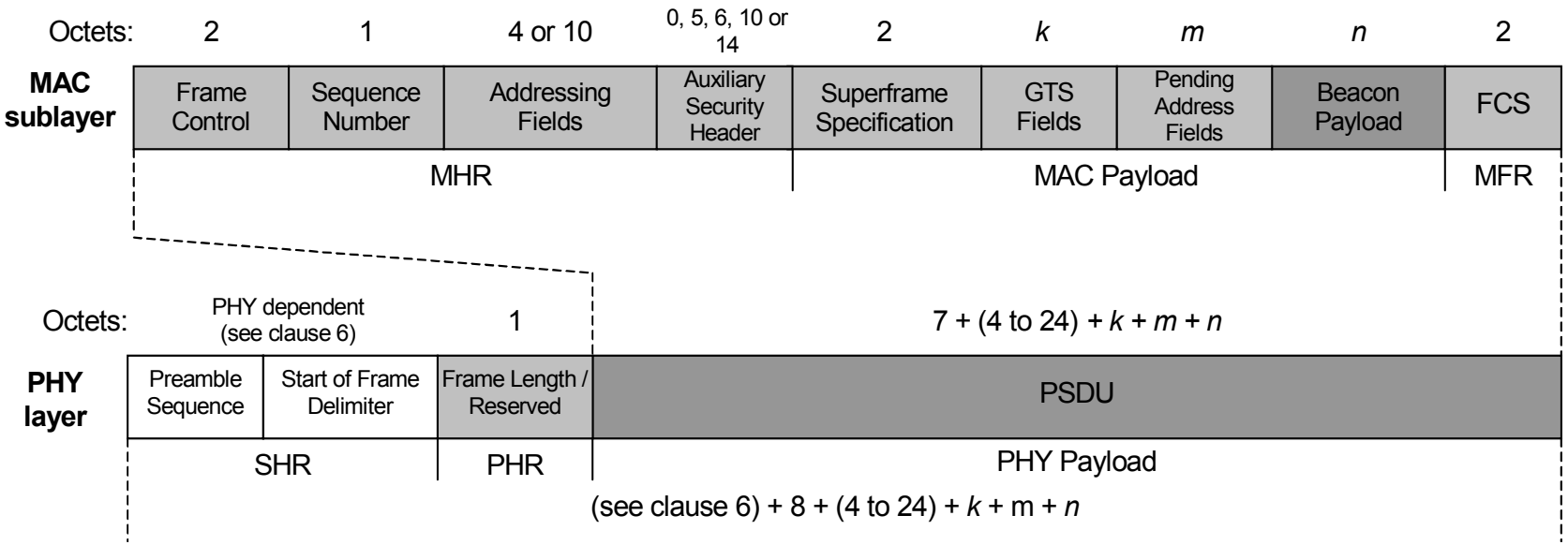


Figure 10—Schematic view of the beacon frame and the PHY packet

Frame structures [2]

Data frame

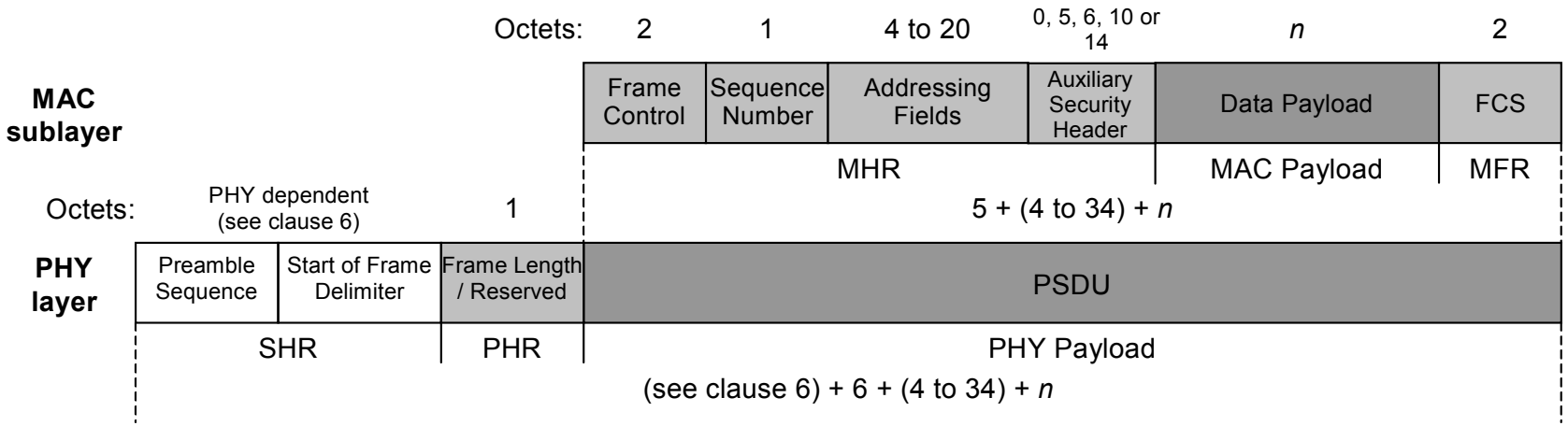


Figure 11—Schematic view of the data frame and the PHY packet

Frame structures [2]

Acknowledgement frame

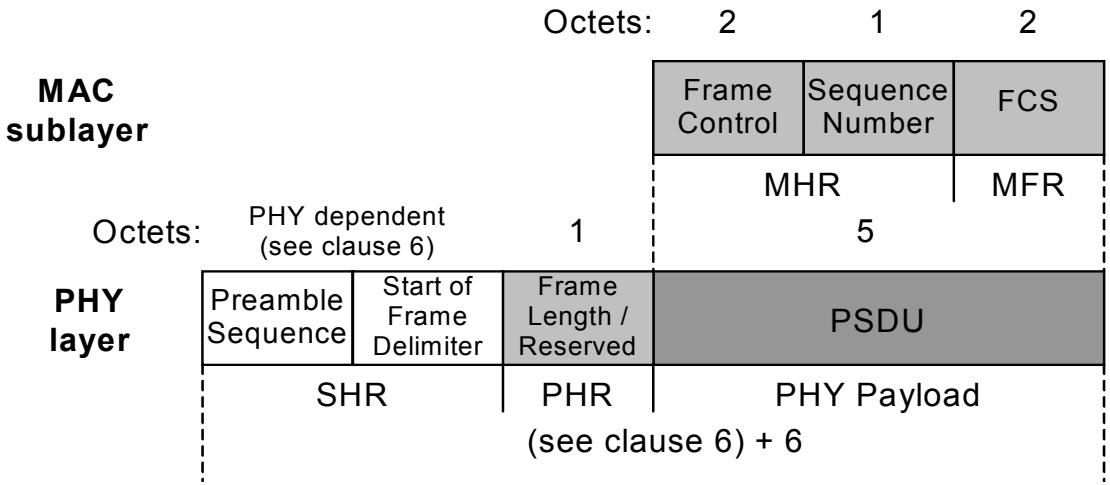


Figure 12—Schematic view of the acknowledgment frame and the PHY packet

Frame structures [2]

Command frame

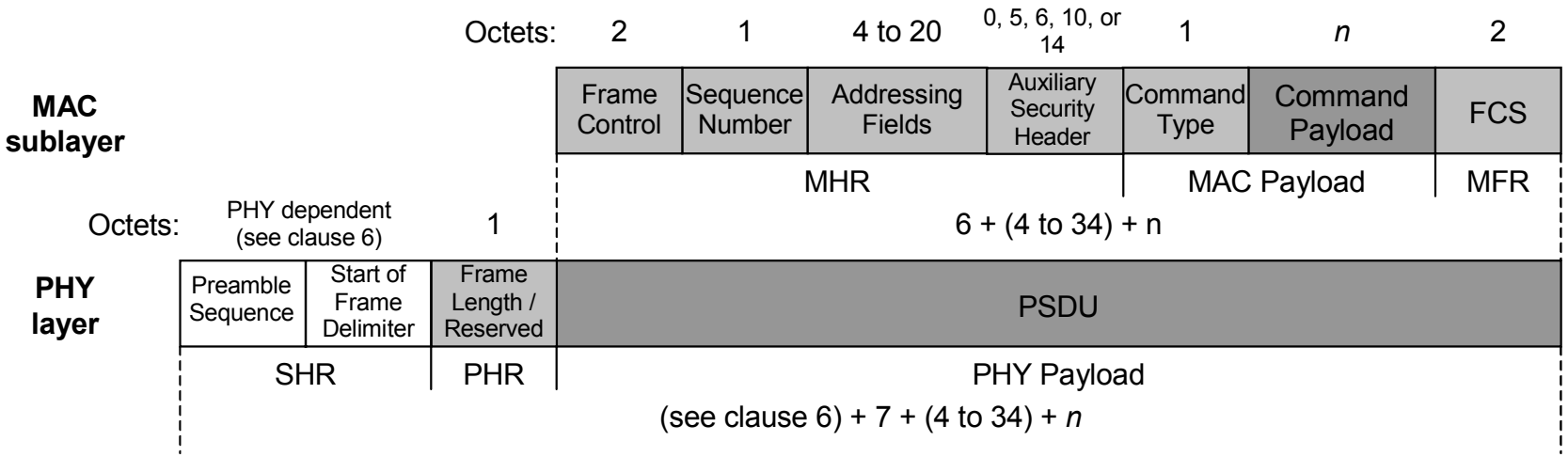


Figure 13—Schematic view of the MAC command frame and the PHY packet

References

[1] ZigBee Alliance - www.zigbee.org
[2] IEEE Std 802.15.4-2006
[3] H. Schwetlick and A. Wolf, PSSS - Parallel Sequence Spread Spectrum - A Physical Layer for RF Communication, 2004
[4] RFC 3561, http://tools.ietf.org/html/rfc3561